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MINIBUS BASED URBAN TRANSPORT PERFORMANCE EVALUATION BY USING DISCRETE EVENT SIMULATION

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ABSTRACT

Nowadays, in many cities in Indonesia, minibus based urban transport faces very serious threat because of its occupation declination. This condition is affected by many factors, such as: the massive usage of private vehicle, the rise of online taxi, vehicle bad condition, and bad driver behavior. This condition triggers the question: is minibus based urban transport still needed? The other question is how to make the minibus based urban transport still survive because lot of workforces and families that their lives is depended on this business. Based on this problem, this research is done to evaluate the performance of the minibus based urban transport. This research is done by using discrete event simulation. In this simulation, the passenger acts as client and the vehicle acts as server. Parameters those are evaluated are the occupation, revenue, and the potential lost. Based on the simulation, the passenger inter-arrival time gives significant impact to the occupation and revenue. The passenger travel distance gives impact only if variable fee method is implemented. The recommended fee so that the vehicle can operate economically is 7,500 rupiah for fixed fee method or 1,000 rupiah per kilometer for variable fee method.

Keywords: *Discrete Event Simulation, Urban Transport, Stochastic, Revenue, Occupation.*

1. INTRODUCTION

Minibus based urban transport (angkot) is one of common urban transportation modes in many cities in Indonesia for decades. Similar to bus based city transport, this mode provides node to node transportation service because it has regular and fix route. This characteristic is different with the taxi which provides door to door transportation service.

Unfortunately, nowadays, minibus based urban transport faces very serious problem. The number of passengers declines so that the business existence is threatened [1,2,5-7]. Lots of route owners stop their operation because the revenue cannot cover the operational cost. Many years ago, when this business is in the golden era, it is easy for local government to open new route or to increase quota in the existing route. Nowadays, the condition is very different. Many minibuses are in poor condition because the owner cannot pay the maintenance cost [1].

Many factors are identified as reasons for this difficult condition. The low down payment that is offered by many leasing companies makes it is easier to buy new vehicle [3,7]. Rapid growth in residential area increases the need in transportation. Unfortunately, this new residential area is not covered by the existing city transport [2]. This condition triggers new business opportunity which is the motorcycle taxi. The motorcycle taxi provides transportation service from the residential area to the street that is covered by the city transport or the opposite. The problem is the fee is very expensive and not transparent. This condition triggers families to have more than one vehicle at home.

Many years ago, family needs one vehicle only, motorcycle or car. Now, it is easy to find more than one vehicle in one family. Small or new family usually has two vehicles, one for the husband and one for the wife. If the child enters senior high school, the parent will buy new vehicle for him so that the child can go to the school by himself. Nowadays, we can see street that is full of motorcycle in the morning. The driver is student, parent, or worker.

The other reason is the driver's bad behavior. Some drivers drive their cars recklessly. Some drivers don't have driving license. Many hawkers operate in the urban transport to catch victim [1,6]. Poor vehicle condition is easily to be found because the owners don't have enough cash to maintain the vehicle and some owners have low customer satisfaction awareness [1,6]. These conditions make the minibus based urban transport is not good choice.

Based on this existing problem, minibus based urban transport evaluation is very important. Some studies have been done based on several disciplines, such as economical or social. The evaluation is needed to answer some important questions. This main research question is in what condition this business is still profitable or economic to be operated.

Simulation can be developed to answer these questions. By using simulation, many conditions and scenarios can be generated to observe the system behavior. That is why there are many researches that focus on simulating public transport system [4,8,9,11-13,15-17]. By using simulation, future condition, such as capacity planning, fleet availability, etc can be observed before the system is implemented to void failure. The problem is the existing simulation researches cannot be implemented directly in minibus based city transport. It is because these researches used bus rapid transit system [4,8,9,11-13] or taxi system [13,15-17] as their research object which their characteristic is different. That is why research in simulating minibus based city transport is important.

Because of this problem, this research purpose is to evaluate the minibus based urban transport performance in Indonesia by using simulation that is developed in this research. This research is done to analyze both financial and non financial aspects. This purpose of this work is also to answer in which condition that the minibus based urban transport is still feasible to be operated. The simulation is developed based on discrete event simulation. This approach is used to simplify the simulation without neglecting the important parameters that shape the system behavior. By using discrete event simulation, the system can be viewed as client-server interaction where the vehicle acts as server and passenger acts as client. This research is also the continuation of the previous research which the object is public transport, especially online motorcycle taxi [15,16].

This paper is organized as follows. In section 1, we explain the background, research question, research purpose, and the paper organization. In section 2, we explain the minibus based urban transport in Indonesia. In section 3, we explain the existing urban transport simulation. In section 4, we explain our proposed model. In section 5, we explain the model implementation into the simulation. In section 6, we explain the discussion and research finding. In section 7, we explain the conclusion and the future work.

2. MINIBUS BASED URBAN TRANSPORT

There are many public transport modes in Indonesia. These transport modes can be grouped into two clusters, motorized and non motorized mode [14]. The various public transport modes but not integrated to each other is the common characteristics in many developing countries. Some of them interact in cooperative situation while the others interact in competitive situation.

There are some common non motorized public transport modes. Becak is the most common type [14]. The main characteristic is its three wheels. Becak is operated by driver behind the passengers. Nowadays some becaks are powered by embedded motorcycle engine. The other mode is dokar. Dokar is cart that powered by horse [14]. Dokar is still used in several regents like Garut or operates around the traditional market. Because these modes are less competitive rather than the motorized ones, in some cities like Yogya and Solo, these traditional modes transform their roles as tourist transportation. Lots of tourists use becak or dokar because of their uniqueness and not because of their efficiency.

In motorized category, there are some modes. The first is bus city transport [14]. This mode usually uses small or medium size bus. The second is minibus city transport [14]. The minibus has lower capacity rather than the bus. In some city, such as Jakarta and Bandung, these two modes operate together. The bus operates in the backbone route while the minibus operates in the non backbone route. While in the other city like Yogyakarta, single managed bus city transport is operated. Both bus and minibus operates in fixed route.

The other motorized transport mode is taxi [14]. Unlike the bus and minibus, taxi doesn’t have fixed route. So, the competitive advantage of taxi is its door to door service. In the fixed route mode, some passengers need to change the vehicle to get their destination. The disadvantage of taxi is the cost is expensive, compared with the fixed route

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mode. There are two types of vehicles that are used as taxi, the two wheels (motorcycle) and four wheels (car).

In Indonesia, minibus based urban transport does not implement fixed stop because there is not any fixed and specified shelters for minibus mode [1]. So, the passengers can hail the vehicle and finish his ride anywhere as far as it is in the minibus route. This condition is also identified as one factor that affects traffic congestion [1]. This condition is different with the condition in the developed country where the city bus stop only in the specified bus shelters.

In minibus modes, competitive situation is applied between vehicle/driver in same route or different route. It makes overtaking between drivers is common. It is because there is no single management that is applied in minibus based mode. Furthermore, driver is paid based on his daily revenue. So, if driver gets higher revenue, he will get better income.

The other unique behavior is staying for a while. Driver usually stays for a while, for example in the intersection and waiting whether there is passenger that will join the vehicle. For some drivers, staying for a while is better than riding with empty seat. In driver's perception, staying for a while can save the fuel cost. The driver will continue riding after he gets new passenger or after stays for certain time, there is still not any new passengers that joins to ride.

The illustration of minibus based mode in Bandung is shown in Figure 1. In Figure 1, it is shown that the vehicle is staying to wait new passenger.

Figure 1: Minibus Based Urban Transport in Bandung, Indonesia

3. EXISTING URBAN TRANSPORT SIMULATION

Many studies have been done in urban transport simulation development. It is because public transport in one of interesting subject. Some studies focus on fixed route transport [4,8,9,11-13] and other studies focus on non fixed route [15,16].

Many studies in fixed route urban transport mode use bus rapid transit as their research object [4-13]. It is because bus rapid transit is very common in many cities in the world. The characteristics of bus rapid transit system are it has fixed route, fixed stop, and single management. Because of its single management, there is not any competition between drivers. Driver usually gets fixed income and the amount is not depended on the number of passenger. Because of there is not any competition, the vehicle usually ride in constant speed. Because of its single management, event there are more than one contractor, there is not any competition between contractors because contractor's revenue is based on the number of vehicles that are operated in the system.

Because the driver behavior is similar, study in bus rapid transit simulation usually uses discrete event simulation (DES) as its platform [11]. It is because DES is simple. Simplification in simulation development makes researcher can focus on the observed parameters. Other research uses agent based modeling [13]. Some parameters that are common in bus rapid transit analysis are capacity, headway [12], door opening and closing time [12], and time between buses.

In the other hand, many studies in non fixed route modes simulation, especially taxi simulation use multi agent system [17]. This approach is chosen because of the assumption that in taxi simulation, which is one of its characteristics is competitive behavior, drivers cannot be generalized. Driver acts based on his goal and his environment status. The observed parameters that are common in taxi simulation are revenue, idle time, pickup time, and delivery time.

4. PROPOSED MODEL

In this research, we develop simulation model based on discrete event simulation. In this model, the minibus or driver acts as server and passenger act as client. The relation between server and client is one-to-many. It means that a single server serves many clients. Event there are more

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than one vehicle on the street, one passenger will be served by one vehicle at one time. In the other side, vehicle can pick up more than one passenger at one time. The number of passengers that can be served by the vehicle at one time is limited by the maximum capacity of the vehicle. In Indonesia, common maximum capacity of minibus based mode is ten passengers. The interior illustration of the vehicle is shown in Figure 2.

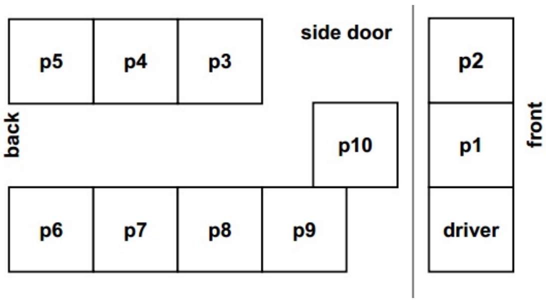

Figure 2: Vehicle Interior

The common configuration of passenger seat in minibus based mode is as follows. Two passengers sit on the front seats beside the driver. Eight passengers sit on the back seats. Passengers who sit on the back seat enter into or exit from the vehicle through the side door.

The vehicle can also be assumed as a set of servers. It is because there are ten seats in the vehicle. So, each seat can be viewed as single server. In this research, the passenger cannot choose the seat. So, the new passenger will be allocated to empty or available seat. The seat position is ignored. The server has two states: available (1) or unavailable (0). The illustration is shown in Figure 3. The grey circle represents unavailable seat while the white circle represents the available seat.

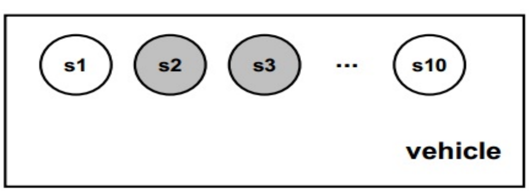

Figure 3: Vehicle as a Set of Servers

The process of serving new passenger is as follows. When there is new passenger or passengers want to join the ride, the system will check the number of available seats. If the number of the empty seats is enough for the number of new passengers, then the new passenger or passengers can be picked up. This action determination is described in Equation 1 and the process algorithm is shown in Figure 4. Variable $n(S_1)$ represents the number of available seats. Variable $n(P_{new})$ represents the number of new passengers. In Figure 4, it is shown that if the new passengers can be picked up, then the number of available seat will be reduced by the number of new passengers.

$$A = \begin{cases} pickup, n(S_1) \geq n(P_{new}) \\ ignore, n(S_1) < n(P_{new}) \end{cases} \qquad (1)$$

```
begin
  if(n(S1)>= n(Pnew)) then
    pickup()
    n(S1)← n(S1)- n(Pnew)
    allocate_passenger()
  else
    ignore()
end
```

Figure 4: New Passenger Process Algorithm

In Figure 4, there is allocate_passenger procedure. This procedure function is to allocate new passengers to the empty seats. Because the passenger cannot choose the seat, for simplification, the seat allocation will be executed based on the seat index priority. The seat allocation algorithm is shown in Figure 5. Variable s represents the seat and j represents the seat index. Variable v represents the state of the seat. So, $v(s_j)$ is the state of seat with index j. Variable c represents the all passengers index. Variable d represents the destination point of the new passenger.

```
begin
  for i=1 to i<=n(Pnew)
  begin
    found ← false
    for j=1 to 8
    begin
      if(v(sj)=1) then
        if(found=false) then
        begin
          c(sj) ← c(pi)
          d(sj) ← d(pi)
          found ← true
        end
      end
    end
  end
end
```

Figure 5: Vehicle as a Set of Servers

In this model, there are four states for the vehicle: ride, stay, drop, and pickup. The ride state is when the vehicle rides on the street. The stay state is when the vehicle stays for a while to wait maybe there is passenger who will join into the vehicle. The pickup state is when the vehicle stops for certain time when the vehicle picks up passenger who wants to join the ride. The drop state is when the vehicle stops for certain time to drop the passenger who wants to finish the ride. The vehicle state diagram is shown in Figure 6.

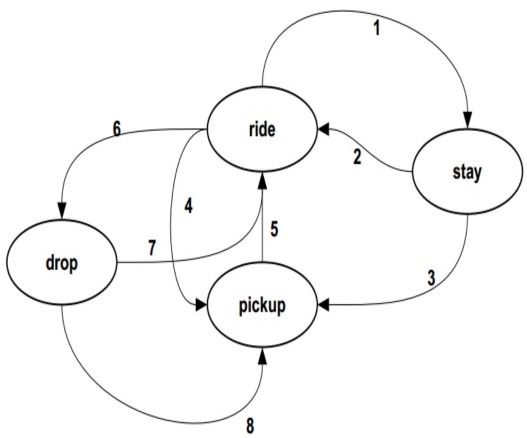

Figure 6: Vehicle State Diagram

In Figure 6, these four states are connected with arrowed line as an event that triggers the state transition. Event 1 occurs when driver decides to stay for a while to wait new passenger. Event 2 occurs when maximum staying time is reached. Event 3 occurs when there is new passenger arrives and joins the ride. Event 4 occurs when there is new passenger stops the vehicle to join the ride. Event 5 occurs when the new passenger has been picked up so the driver decides to continue the ride. Event 6 occurs when there is passenger decides to stop the ride so that the passenger will be dropped off at the intended point. Event 7 occurs when the passenger has been dropped so that the driver can continue the ride. Event 8 occurs when after the passenger has been dropped off, there is new passenger that wants to join the ride at the same point.

While the driver is riding, the system always checks whether the vehicle reaches any passenger's destination. If the vehicle position is near by the passenger's destination then the vehicle will stop to drop the passenger whose destination point near by the vehicle point. To define that the vehicle point is near by the passenger's destination, the tolerance radius (r_{tol}) is used. This action is described in Equation 2. The algorithm of this process is shown in Figure 7. In Equation 2, variable p(v) represents the vehicle position and variable S represents set of vehicle seats. After the passenger exit the vehicle, the seat then will be set available again.

$$A = drop \| \|d(s) - p(v)\| \leq r_{tol} \wedge s \in S \quad (2)$$

```
begin
  for i=1 to 8
  begin
    if rtol>abs(d(si)-p(v)) then
    begin
      v(si)← 0
      n(S1)←n(S1) + 1
    end
  end
end
```

Figure 7: Destination Reached Checking Algorithm

During riding, the vehicle may stop and stay for a while. To determine whether the vehicle will stop to stay, a random number will be generated when the vehicle begins to ride after it picks up new passenger, drops passenger, or stays for a while. The random number is represented by variable $t_{nextstay}$. If the riding time reaches the $t_{nextstay}$ then the vehicle will stop and stay. This process is described in Equation 3. When the vehicle action is stay, the random number is generated to determine the maximum stay time ($t_{maxstay}$). This random number is generated and follows exponential distribution with the average value is $t_{avgmaxstay}$. This process is described in Equation 4.

$$A = stay | t_{ride} \geq t_{nextstay} \quad (3)$$

$$t_{\max stay} = random(t_{avg \max stay}) \quad (4)$$

The vehicle state will change to two possible states: pickup or ride. The state will be set to pickup if there is passenger that joins the ride. The state will be set ride if the vehicle stay time (t_{stay}) reaches the maximum stay time ($t_{maxstay}$). This process is shown in Equation 5. If the vehicle action is ride then the t_{ride} is set 0.

$$A = \begin{cases} ride, t_{stay} \geq t_{\max stay} \\ pickup, n(S_1) \geq n(P_{new}) \wedge n(P_{new}) > 0 \end{cases} \quad (5)$$

Basically, the route can be viewed as a single closed loop or a single straight line. When the route is viewed as a single closed loop, the vehicle runs in a single direction, clock wise or counter clock wise. When the vehicle completes the lap, the vehicle is on the position where it starts riding. The vehicle can start at any position in the loop. The route length is the loop circumference. When the route is viewed as a single straight line, the line has two edges, the start node and the end node. If the straight line is assumed horizontal, then the start node is on the left edge and the end node is on the right node. The vehicle can start anywhere in the line. The vehicle rides in a single direction, for example to the right. When the vehicle reaches the end node, the vehicle position will be set at the start node. This illustration is shown in Figure 8.

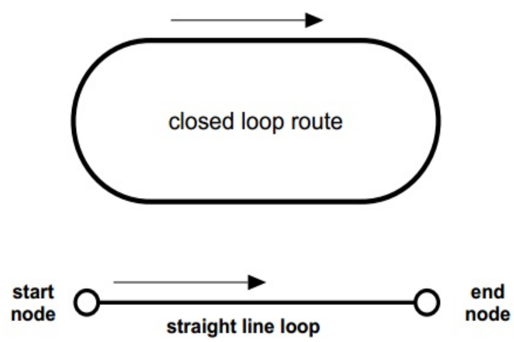

Figure 8: Route Abstraction

5. IMPLEMENTATION

After the model has been developed, then the model is implemented into simulation application. The simulation is developed based on PHP language. The reason of using PHP is that this language is easy to use and the application is light in computation.

The simulation is run for specified time called simulation time (t_{sim}). In this simulation application, the t_{sim} is represented in iteration. One iteration cycle represents one second simulation time. For example, if we want to simulate the vehicle that operates for one hour, then the number of iteration will be 3600.

In this research, in one simulation session, the number of vehicles is one. It means that there are not any other vehicles in the route. The route length is set 30 kilometer. The vehicle speed is static and it is set approximately 15 kilometer per hour or 4 m/s. So, without stopping, the vehicle can complete one lap in 7,500 second or approximately 2 hours. Event the maximum speed of the vehicle is more than that number, the traffic situation cannot be ignored. The average drop off and pickup duration is set 10 seconds.

The passenger that wants to join the vehicle appears randomly. The passenger's inter arrival time follows exponential distribution with the specified average value. When the passenger joins the ride, the passenger's destination position is set too and the value follows exponential distribution.

When the passenger reaches the destination, he will pay some money as travel fee. In this research, there are two types of charging method: fixed fee and variable fee. When fixed fee is implemented, the fee for every passenger is fixed and the travel distance is ignored. When variable fee is implemented, the amount of fee is depended on the travel distance with minimum fee. The fee calculation is shown in Equation 6. In Equation 6, m_{tot} represents the total fee that must be paid by the passenger. Variable r_{dist} is the passenger's travel distance at it is presented in kilometer. Variable m_{min} represents the minimum fee. The m_{var} is the variable fee and is it is presented in rupiah per kilometer.

$$m_{tot} = m_{\min} + (\, floor(r_{dist}) + 1) \times m_{\mathrm{var}} \quad (6)$$

The illustration of Equation 6 is as follows. Supposed that there is a passenger that needs to travel with the travel distance is 8.5 kilometer. The minimum fee is 2000 rupiah. The variable fee is 500 rupiah per kilometer. So, the total fee that must be paid by this customer when he finishes the ride is 6.500 rupiah.

6. TESTING AND DISCUSSION

As it is mentioned in the research purpose, this simulation is a tool to evaluate the minibus based urban transport performance. The evaluation is focused on answering questions: in which situations are the minibus based urban transport is still profitable to operate. To answer this question, several tests are done to observe the output parameters by adjusting the input parameter. For each test, the simulation session runs for 10 hours vehicle operation in the real world and it is equivalent with 36.000 iterations.

During the test, parameter default value must be set. Based on field observation, in each passenger's arrival event, the number of passengers

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can be group into two: one passenger and two passengers. The distribution is discrete. The distribution of one passenger is 25 percent while the distribution of two passengers is 75 percent. Meanwhile, in two passengers that join the ride for the same time, the destination point or the travel distance may be different. The other parameters default value is shown in Table 1.

Table 1: Simulation Default Value

Parameter	Default Value
Inter arrival time	557 second
Travel distance	5 km
Staying time	87 second
Inter staying time	797 second
Fixed fee	5,000 rupiah
Variable fee	500 rupiah/km

In all tests, there are two types of outputs that are observed: financial output and non financial output. The financial output is the vehicle revenue. The revenue is calculated by both fixed fee and variable fee. The non financial outputs are the number of passenger that can be picked up, the number of passenger that are fail to be picked up, and the maximum number of passengers that are in the vehicle. The number of passengers that are failed to be picked up is important aspect to be observed to evaluate the potential lost.

Based on the research purpose that is to evaluate the economic condition, the operational cost must be calculated. In this research, the daily direct operational cost is the fuel cost and the driver cost. Based on the assumption that the vehicle speed is 15 kilometer per hour so in 10 hours operation, the travel distance is 150 km. If one liter of gasoline can be used for 10 km travel distance in city traffic situation, the fuel consumption for one day operation will be 15 liters. Suggest that the fuel price is 8,000 rupiah per liter. So, the fuel cost is 120,000 rupiah. If the daily driver cost is 200,000 rupiah, so the daily operational cost is 320,000 rupiah. The maintenance cost has not been calculated.

The next assumption is if the vehicle is bought by loan with the installment is 3,000,000 rupiah per month. If the vehicle is operated 30 days in a month, the daily installment cost is 100,000 rupiah. If the vehicle owner wants to receive minimum daily net revenue 200,000 rupiah so the daily revenue must be at least 620,000 rupiah.

In the first test, we observe the relation between passenger inter-arrival time and the output parameters. The average passenger-inter arrival time range is from 5 minutes until 15 minutes with step size is one minute. In this test, the other parameters are set in default value. There are 5 simulation session for each inter arrival step. The result is shown in Table 2.

Table 2: Relation Between Passenger Inter Arrival Time, Non Financial Result, and Financial Result

t_{int} (minutes)	Non Financial Aspect			Financial Aspect (Revenue)	
	$n_{maxload}$ (seats)	n_{lost} (person)	n_{pickup} (person)	Fix fee (rupiah)	Variable fee (rupiah)
5	10	26	152	760,714	716,857
6	10	20.2	155.8	779,000	740,100
7	10	11	143	715,000	655,900
8	10	8.2	131.8	659,000	602,400
9	10	6	119	595,000	561,700
10	9.2	2	96	480,000	437,100
11	9.4	0.2	85.6	428,000	396,500
12	8.8	0	76.8	384,000	358,400
13	9.6	2.4	87.2	436,000	400,100
14	9.2	0	75.8	379,000	339,000
15	8.2	0.4	71.4	357,000	320,300

Based on data in Table 2, it can be seen that the increasing in passenger inter arrival time reduces the number of passenger that is picked up significantly. The number of passengers that can be picked up when the inter arrival interval is 15 minutes is less than 50 percents rather than when the inter arrival interval is 5 minutes. When the inter arrival interval is increasing, the number of passengers that is fail to be picked up also decreases significantly.

Based on data in Table 2, it can be seen that the increasing of the passenger inter arrival interval reduces the revenue significantly. Based on fix fee method, the vehicle is economic to be operated if the passenger inter arrival is less than 9 minutes. Based on the variable fee method, the vehicle can operate economically if the passenger inter arrival interval is less than 8 minutes.

In the second test, we observe the relation between passenger travel distance and the output parameters. The average passenger travel distance is set from 3 kilometers to 8 kilometers with the step size is 1 kilometer. In this test, the other parameters are set in default value. There are 5 simulation sessions for each passenger travel distance step. The result is shown in Table 3.

Table 3: Relation Between Passenger Travel Distance, Non Financial Result, and Financial Result

r_{dist} (km)	Non Financial Aspect			Financial Aspect (Revenue)	
	$n_{maxload}$ (seats)	n_{lost} (person)	$n_{maxload}$ (seats)	Fix fee (rupiah)	Variable fee (rupiah)
3	8.2	0	103.6	518,000	383,900
4	9.8	2.8	111.8	559,000	483,600
5	9.8	4.6	99.2	496,000	483,500
6	10	7.8	111	555,000	561,500
7	10	7.8	96.2	481,000	553,600
8	10	15.4	104.4	522,000	682,800

Based on data in Table 3, it can be seen that the increasing of the passenger travel distance makes the number of passengers that is fail to be picked up increase significantly. In the other hand, the increasing of the passenger travel distance does not affect the number of passengers that is picked up successfully.

Based on data in Table 3, it can be seen that in the fix fee method, the travel distance does not affect the daily revenue. In the other hand, in the variable fee method, the increasing of the travel distance makes the revenue increase significantly. In the fix fee method, the vehicle cannot operate economically. In variable fee method, the vehicle can operate economically if the passenger travel distance is higher than 7 kilometers.

In the third test, we observe the relation between vehicle staying time and the output parameters. The average passenger staying time is set from 3 minutes to 8 minutes with the step size is 1 minute. In this test, the other parameters are set in default value. There are 5 simulation session for each vehicle staying time step. The output result is shown in Table 4.

Based on data in Table 4, it can be seen that the increasing of the vehicle staying time increases the number of passengers that is fail to be picked up but it is not significant. In the other hand, the increasing of the vehicle staying time reduces the number of passengers that is picked up successfully but it is not significant too. So, it can be said that the staying behavior gives negative non financial impact to the driver and the passenger.

Table 4: Relation Between Vehicle Staying Time, Non Financial Result, and Financial Result

t_{stay} (minutes)	Non Financial Aspect			Financial Aspect	
	$n_{maxload}$ (seats)	n_{lost} (person)	n_{pickup} (person)	Fix fee (rupiah)	Variable fee (rupiah)
3	10	5.2	110	550,000	513,000
4	10	5.8	114.6	573,000	543,700
5	9.8	6.8	111.8	559,000	516,400
6	10	5.8	109.2	546,000	508,100
7	9.8	7.8	117.4	587,000	542,200
8	10	7	101.6	508,000	468,500

Based on data in Table 4, it can be seen that in the fix fee method, the staying time does not affect the revenue. In the variable fee method, the increasing staying time tends to reduce the revenue. In both methods, the vehicle cannot operate economically. So, it can be said that staying behavior gives negative financial impact to the driver.

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In the fourth test, we observe the relation between vehicle inter-staying time and the output parameters. The average passenger inter-staying interval is set from 5 minutes to 15 minutes with the step size is 1 minute. In this test, the other parameters are set in default value. There are 5 simulation session for each vehicle inter-staying time step. The result is shown in Table 5.

Table 5: Relation Between Vehicle Inter-Staying Time, Non Financial Result, and Financial Result

$t_{int\text{-}stay}$ (minutes)	Non Financial Aspect			Financial Aspect	
	$n_{maxload}$ (seats)	n_{lost} (person)	n_{pickup} (person)	Fix fee (rupiah)	Variable fee (rupiah)
5	10	5.8	112.2	561,000	512,400
6	9.6	2.2	93.6	468,000	425,200
7	9.8	5	104.6	523,000	477,600
8	10	5.2	111.6	558,000	533,700
9	10	6.8	116.4	582,000	551,000
10	10	7.6	122.2	611,000	569,500
11	9.6	4	106.4	532,000	480,300
12	10	4	110.8	554,000	515,600
13	10	5.4	110.6	553,000	513,600
14	9.6	2.8	112.4	562,000	537,200
15	9.8	6.4	116	580,000	548,700

Based on Table 5, it is shown that the vehicle inter staying time does not affect both number of passengers that can be picked up or the number of passengers that is fail to be picked up. This parameter does not affect the maximum number of passengers too. It is also shown that the vehicle inter staying interval does not affect the revenue. This condition occurs both in the fix fee method and in the variable fee method. After those simulation tests, the next observation is comparing the revenue between various fee options. This observation includes fixed fee option and variable fee option. The fixed fee options are 5,000; 7,500; and 10,000 rupiah. The variable fee options are 500; 1,000; and 1,500 rupiah per kilometer. The first revenue comparison is for passenger inter-arrival time. The result is shown in Table 6.

Table 6: Revenue Comparison for Different Passenger Inter Arrival Time

t_{int} (minutes)	Fixed Fee Based Revenue (rupiah)			Variable Fee Based Revenue (rupiah)		
	5,000 rupiah	7,500 rupiah	10,000 rupiah	500 Rp/km	1,000 Rp/km	1,500 Rp/km
5	760,714	1,141,071	1,521,429	716,857	1,129,429	1,542,000
6	779,000	1,168,500	1,558,000	740,100	1,168,600	1,597,100
7	715,000	1,072,500	1,430,000	655,900	1,025,800	1,395,700
8	659,000	988,500	1,318,000	602,400	941,200	1,280,000
9	595,000	892,500	1,190,000	561,700	885,400	1,209,100
10	480,000	720,000	960,000	437,100	682,200	927,300
11	428,000	642,000	856,000	396,500	621,800	847,100
12	384,000	576,000	768,000	358,400	563,200	768,000
13	436,000	654,000	872,000	400,100	625,800	851,500
14	379,000	568,500	758,000	339,000	526,400	713,800
15	357,000	535,500	714,000	320,300	497,800	675,300

Based on data in Table 6, it is shown that in the fixed method, the relation between passenger inter-arrival interval and the fee option affects the economic threshold. When the fee is 5,000 rupiah, the vehicle can operate economically if the passenger inter-arrival interval is under 9 minutes. When the fee is 7,500 rupiah, the vehicle can operate economically if the passenger's inter arrival interval is under 12 minutes. When the fee is 10,000 rupiah, the vehicle can operate economically in all range of passenger inter-arrival time.

Based on data in Table 6, it is shown that in the variable fee method, the relation between

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passenger inter-arrival time and the unit fee option affects the economic threshold. When the unit fee is 500 rupiah per kilometer, the vehicle can operate economically if the passenger inter-arrival interval is under 9 minutes. When the unit fee is 1,000 rupiah per kilometer, the vehicle can operate economically if the passenger inter-arrival interval is under 12 minutes. When the unit fee is 1,500 rupiah per kilometer, the vehicle can operate economically in all range of passenger inter arrival interval.

The second revenue comparison is for the different passenger travel distance. The result is shown in Table 7.

Table 7: Revenue Comparison for Different Passenger Travel Distance

r_{dist} (km)	Fixed Fee Based Revenue (rupiah)			Variable Fee Based Revenue (rupiah)		
	5,000 rupiah	7,500 rupiah	10,000 rupiah	500 Rp/km	1,000 Rp/km	1,500 Rp/km
3	518,000	777,000	1,036,000	383,900	560,600	737,300
4	559,000	838,500	1,118,000	483,600	743,600	1,003,600
5	496,000	744,000	992,000	483,500	768,600	1,053,700
6	555,000	832,500	1,110,000	561,500	901,000	1,240,500
7	481,000	721,500	962,000	553,600	914,800	1,276,000
8	522,000	783,000	1,044,000	682,800	1,156,800	1,630,800

Based on data in Table 7, it is shown that in the fixed fee method, the fee option gives more impact rather than passenger travel distance. When the fee is 5,000 rupiah, the vehicle cannot operate economically. The vehicle can operate economically when the fee is 7,500 rupiah or 10,000 rupiah.

Based on data in Table 7, it is shown that in the variable fee method, the fee option changes the economical threshold of the passenger travel distance. When the unit fee is 500 rupiah per kilometer, the vehicle can operate economically if the passenger' travel distance is higher than 7 kilometers. When the unit fee is 1,000 rupiah per kilometer, the vehicle can operate economically if the passenger' travel distance is higher than 3 kilometers. When the unit fee is 1,500 rupiah per kilometer, the vehicle can operate economically in all range of passenger's travel distance.

The third revenue comparison is for the different vehicle staying time. The result is shown in Table 8.

Table 8: Revenue Comparison for Different Vehicle Staying Time

t_{stay} (minutes)	Fixed Fee Based Revenue (rupiah)			Variable Fee Based Revenue (rupiah)		
	5,000 rupiah	7,500 rupiah	10,000 rupiah	500 Rp/km	1,000 Rp/km	1,500 Rp/km
3	550,000	825,000	1,100,000	513,000	806,000	1,099,000
4	573,000	859,500	1,146,000	543,700	858,200	1,172,700
5	559,000	838,500	1,118,000	516,400	809,200	1,102,000
6	546,000	819,000	1,092,000	508,100	797,800	1,087,500
7	587,000	880,500	1,174,000	542,200	849,600	1,157,000
8	508,000	762,000	1,016,000	468,500	733,800	999,100

Based on data in Table 8, it is shown that the vehicle staying time does not affect the revenue. This condition occurs in the fixed fee or the variable fee methods. In the fixed fee method, the vehicle can operate economically if the fee is equal to or higher than 7,500 rupiah. In the variable fee method, the vehicle can operate economically if the unit fee is equal to or higher than 1,000 rupiah per kilometer.

The fourth revenue comparison is for the different vehicle inter-staying time. The result is shown in Table 9.

Table 9: Revenue Comparison for Different Vehicle Inter-Staying Time

t_{stay} (minutes)	Fixed Fee Based Revenue (rupiah)			Variable Fee Based Revenue (rupiah)		
	5,000 rupiah	7,500 rupiah	10,000 rupiah	500 Rp/km	1,000 Rp/km	1,500 Rp/km
5	561,000	841,500	1,122,000	512,400	800,400	1,088,400
6	468,000	702,000	936,000	425,200	663,200	901,200
7	523,000	784,500	1,046,000	477,600	746,000	1,014,400
8	558,000	837,000	1,116,000	533,700	844,200	1,154,700
9	582,000	873,000	1,164,000	551,000	869,200	1,187,400
10	611,000	916,500	1,222,000	569,500	894,600	1,219,700
11	532,000	798,000	1,064,000	480,300	747,800	1,015,300
12	554,000	831,000	1,108,000	515,600	809,600	1,103,600
13	553,000	829,500	1,106,000	513,600	806,000	1,098,400
14	562,000	843,000	1,124,000	537,200	849,600	1,162,000
15	580,000	870,000	1,160,000	548,700	865,400	1,182,100

Based on data in Table 9, it is shown that the vehicle inter staying time does not affect the revenue. This condition occurs in the fixed fee or the variable fee methods. In the fixed fee method, the vehicle can operate economically if the fee is equal to or higher than 7,500 rupiah. In the variable fee method, the vehicle can operate economically if the unit fee is equal to or higher than 1,000 rupiah per kilometer.

7. CONCLUSION AND FUTURE WORK

Based on the explanation above, it can be concluded that the proposed model has been implemented successfully into the minibus based urban transport simulation application. Some scenarios have been done in the simulation to find the aspects that have significant impact in minibus based urban transport performance. Several tests have been done to find the condition whether the vehicle can operate economically.

Based on the tests, some parameters have significant influence while the others do not have significant influence. The increasing of passenger inter-arrival time gives significant influence in reducing the number of passengers that can be picked up by the vehicle and the revenue. In the fixed fee method, the passenger travel distance does not affect the revenue. In the variable fee method, the increasing of passenger travel distance gives significant influence in increasing the revenue. The driver staying behavior does not increase the driver revenue.

The most significant parameter that affects the economical level of the vehicle is the fee. In the fixed fee method, the vehicle can operate economically if the fee is equal to or higher than 7,500 rupiah. When the fee is below 7,500 rupiah, the operational is very risky. When the fee is 5,000 rupiah, the vehicle can operate economically if the passenger inter-arrival time is less than 9 minutes. In the variable fee method, the vehicle can operate economically if the unit fee is equal to or higher than 1,000 rupiah per kilometer. If the unit fee is 5,000 rupiah, the vehicle can operate economically if the passenger inter arrival interval is less than 8 minutes. So, in this research the fee recommendation is 7,500 rupiah for fixed fee method and 1,000 rupiah per kilometer for variable fee method.

In the future, there are lots of research potentials in public transport simulation research. There are many public transport modes in urban area. How to coordinate the transportation modes is a big challenge. The main goal is to harmonize the transportation modes as far as it is good for all stakeholders: the passenger, the driver, the business owner, and the government.

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